Power factor correction IC: FA1B00N
Power supply design example: 24 V / 60 W

Reference Design

1. Overview

This document is a design example of a PFC flyback converter using the power factor correction control IC FA1B00N. The output power is 60W. It can be applied to power supplies for LED lighting.

2. Features of FA1B00N

- ✓ High-precision over current protection: 0.65 V ± 2 %
- ✓ Low current consumption by CMOS process
- ✓ Start-up : 300 µA (max.), Operating : 1.2 mA (typ.)
- ✓ Enabled to drive power MOSFET directly

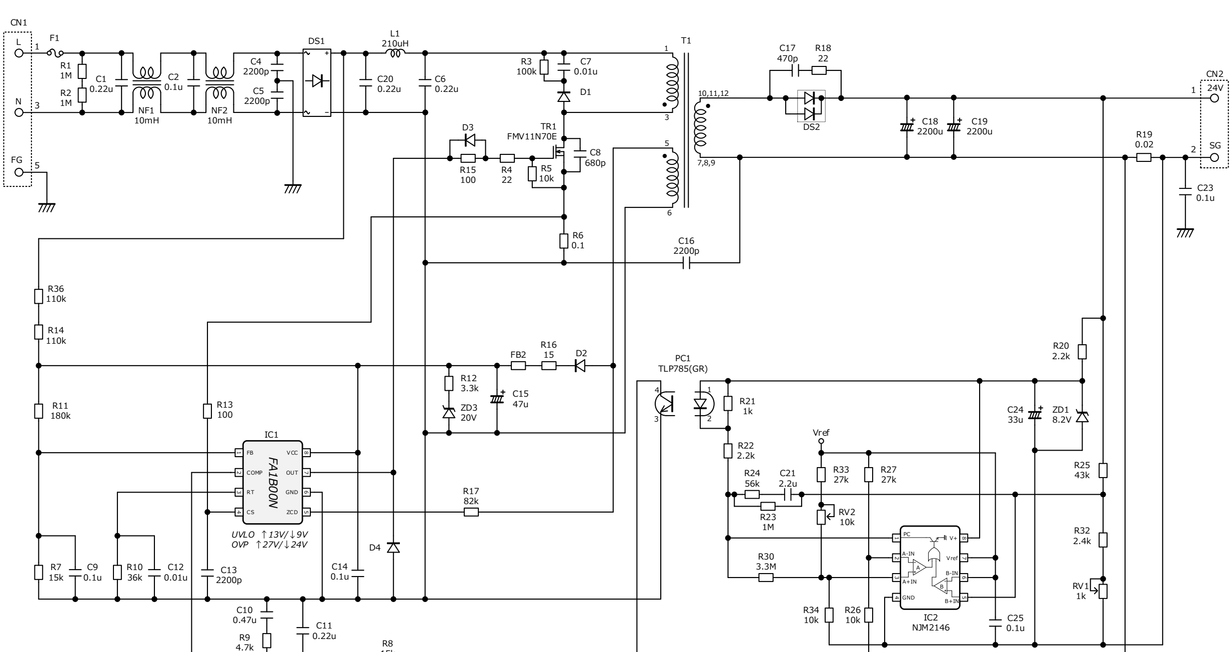
  Output peak current, source : 0.5 A, sink : 1 A
- ✓ Under-voltage Lockout, 13 V ON / 9 V OFF

2. Power supply specifications

- ✓ Flyback converter with improved power factor
- ✓ LED load can be directly connected thanks to CV/CC control

Item	Value	Unit
Input voltage range	90 to 264	Vac
Adjustable output voltage range	21 to 28	Vdc
Adjustable output current range	0.1 to 2.5	A
Maximum output power	60	W

4. Circuit diagram



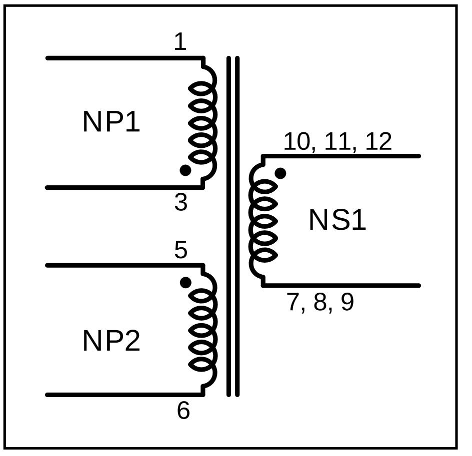
5. Parts list

Component	Item	Value	Parts No.	Maker
T1	Transformer		PQ3220	
NF1, 2	Inductor	3A/10mH		
L1	Inductor	3A/210uH		
FB2	Ferrite bead			
C1	Film capacitor	310V/0.22uF	LE224-M	OKAYA
C2	Film capacitor	310V/0.1uF	LE104-MX	OKAYA
C3	Film capacitor	310V/0.22uF		
C4, 5, 16	Ceramic capacitor	2200pF	DE1E3KX222MA4BL01	MURATA
C6, 20	Film capacitor	450V/0.22uF	ECWFD2W224J	Panasonic
C7	Film capacitor	630V/0.01uF	ECQE6103KF	Panasonic
C8	Ceramic capacitor	1kV/680pF	DEHR33A681KA2B	MURATA
C9, 14, 25	Ceramic capacitor	0.1uF		
C10	Ceramic capacitor	0.47uF		
C11	Ceramic capacitor	0.22uF		
C12	Ceramic capacitor	0.01uF		
C13	Ceramic capacitor	2200pF		
C15	Electrolytic capacitor	47uF		
C17	Ceramic capacitor	1kV/470pF	DEHR33A471KA2B	MURATA
C18, 19	Electrolytic capacitor	35V/2200uF		
C24	Electrolytic capacitor	35V/33uF		
C21	Ceramic capacitor	2.2uF		
C23	Film capacitor	630V/0.1uF	ECQE6104KF	Panasonic
R1, 2	Resistor	1MΩ		
R3	Resistor	100kΩ		
R4, 18	Resistor	22Ω		
R5, 26, 34	Resistor	10kΩ		
R6	Resistor	0.1Ω		
R7, 8	Resistor	15kΩ		
R11	Resistor	180kΩ		
R9	Resistor	4.7kΩ		
R10	Resistor	36kΩ		
R12	Resistor	3.3kΩ		
R13, 15	Resistor	100Ω		
R14, 36	Resistor	110kΩ		
R16	Resistor	15Ω		
R20, 22	Resistor	2.2kΩ		
R21	Resistor	1kΩ		
R23	Resistor	1MΩ		
R24	Resistor	56kΩ		
R25	Resistor	43kΩ		
R27, 33	Resistor	27kΩ		
R30	Resistor	3.3MΩ		
R32	Resistor	2.4kΩ		
R19	Resistor	0.02Ω		
R17	Resistor	82kΩ		
RV1	Variable resistor	1kΩ		
RV2	Variable resistor	10kΩ		
D1	Diode	1000V/0.5A		
D2, 3	Diode	200V/1A		
D4	Diode	40V/1A		
ZD1	Zener diode	200mW/8.2V		
ZD3	Zener diode	200mW/20V		
DS1	Bridge Diode	600V/4A		
DS2	Diode	200V/30A	YG878C20R	Fuji
TR1	MOSFET	700V/11A	FMV11N70E	Fuji
IC1	IC		FA1B00N	Fuji
IC2	IC		NJM2146BM	JRC
PC1	Photo coupler			

6. Transformer (T1)

Item	Value	Note
Core size	PQ 32/20	
Inductance	260μH	1 pin to 3 pin
NP1	24 turn	start 3 pin end 1 pin
NP2	4 turn	start 5 pin end 6 pin
NS1	5 turn	start 10, 11, 12 pin end 7, 8, 9 pin

Wiring diagram

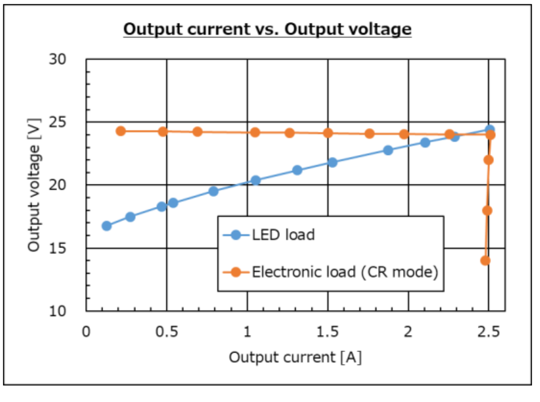


7. CV and CC control output characteristics

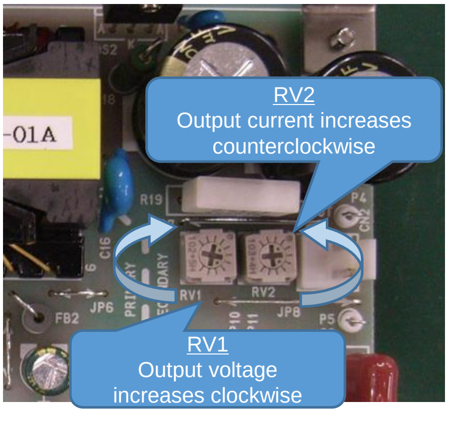
The output of the reference board is controlled as CV or CC depending on the connected load.

- ✓ When a resistive load is connected, the output constant voltage is adjusted by RV1 and the output current limit is adjusted by RV2.
- ✓ When the LED load is connected, the output constant current is adjusted by RV2, and the output voltage limit is adjusted by RV1.

Output characteristics of LED load and electronic load

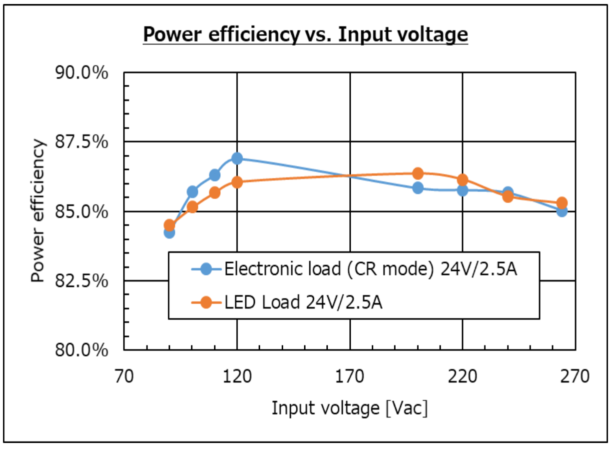


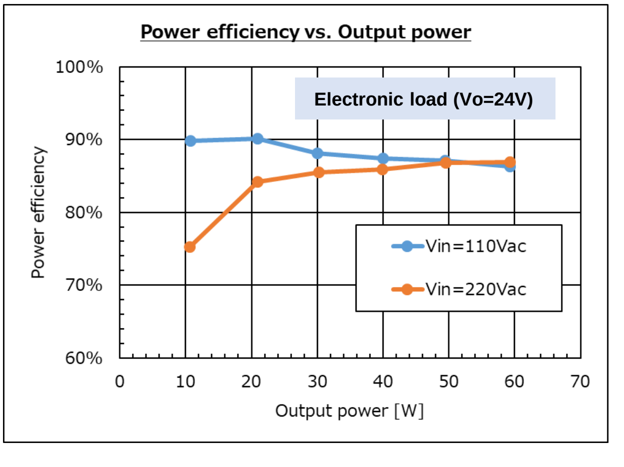
Output voltage and Output current adjustment point

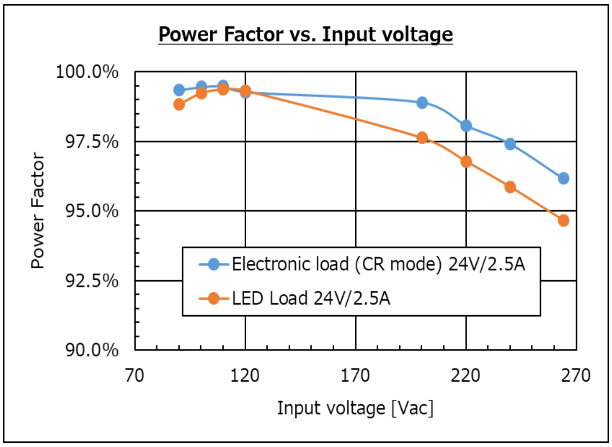


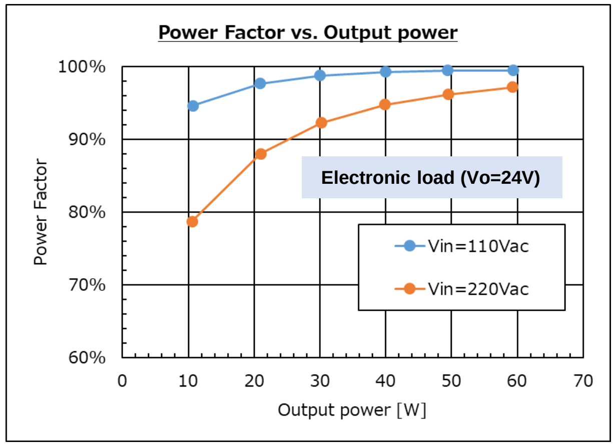
8. Electrical characteristics

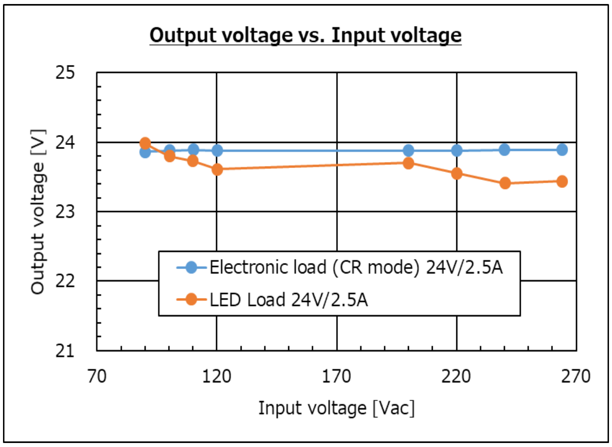
The input / output characteristics of the reference board are as follows.

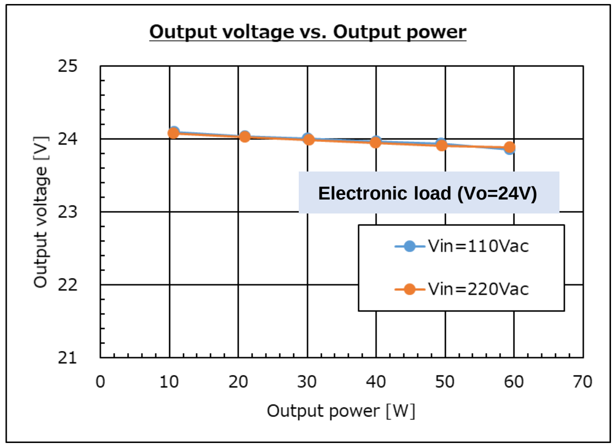


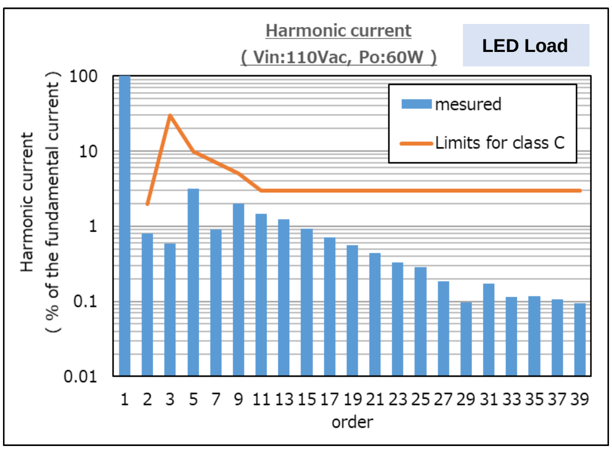


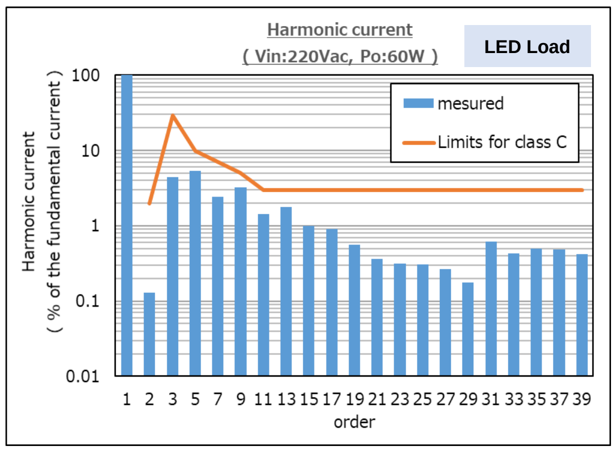






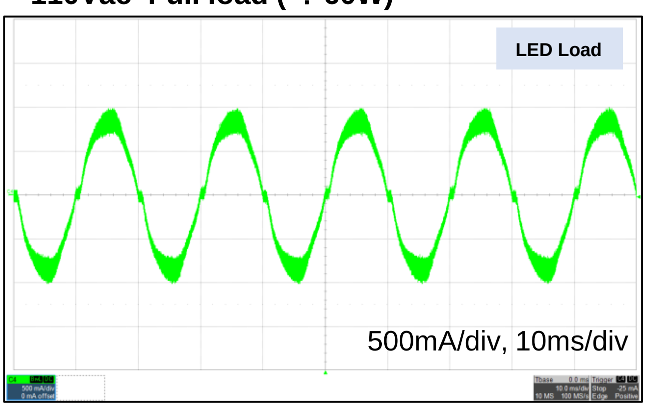




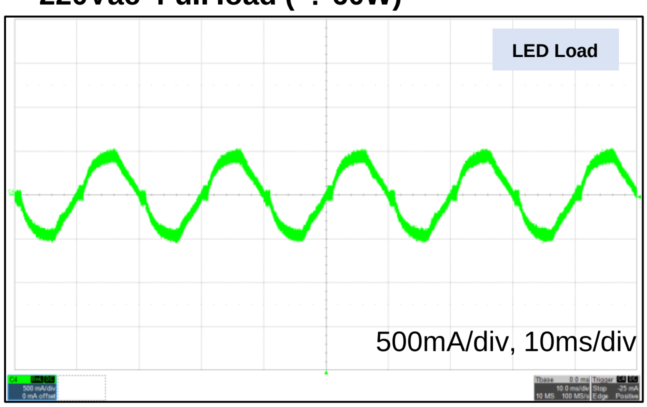


9. Waveforms (AC input current)

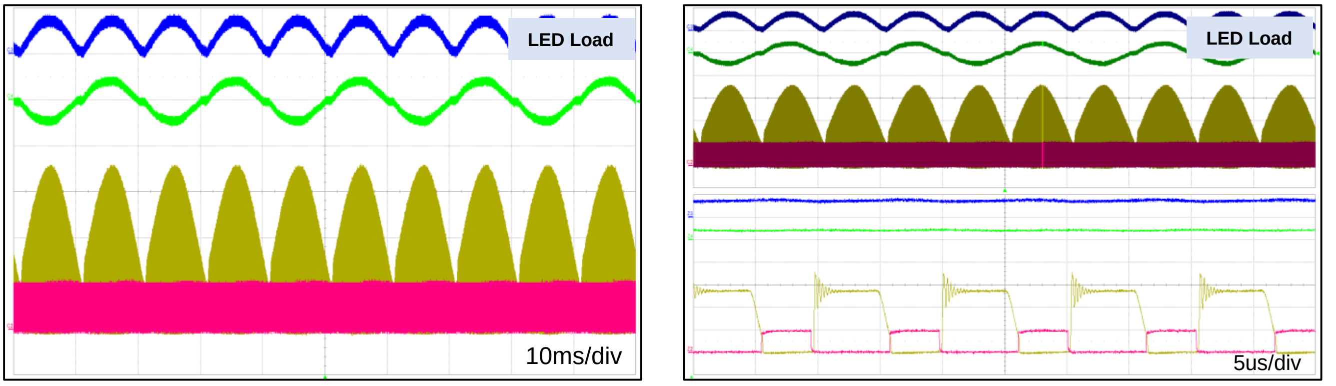
110Vac Full load (≒ 60W)



220Vac Full load (≒ 60W)

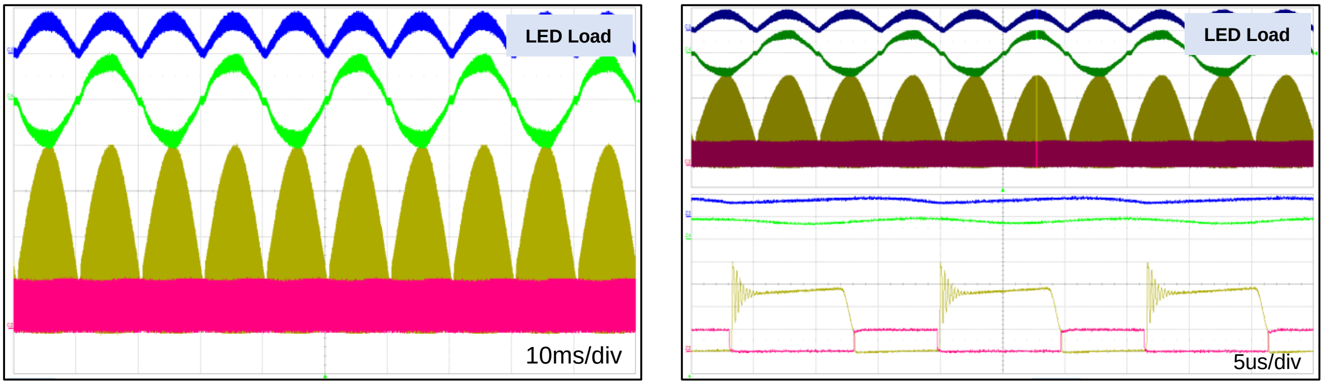


◆110Vac Half load (≒ 30W) Switching wave form



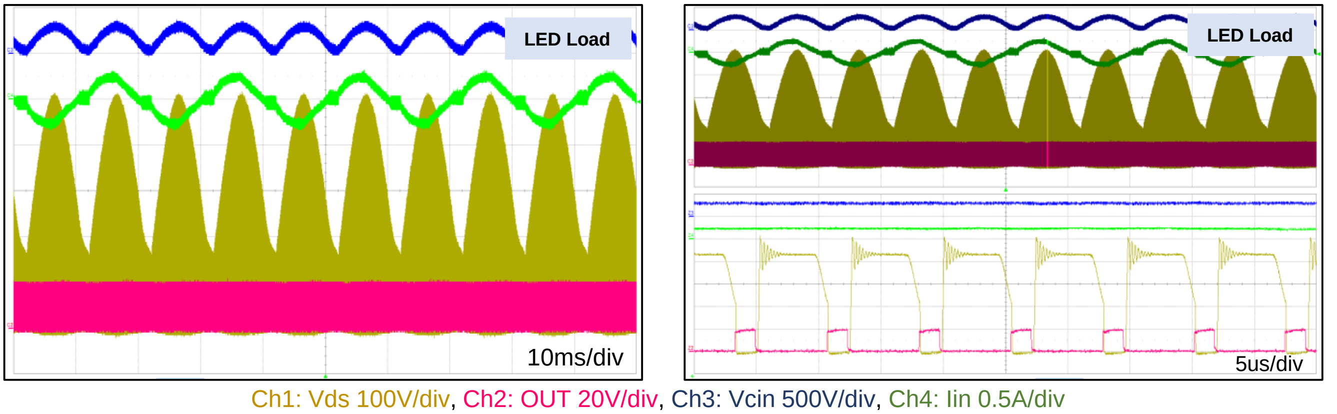
Ch1: Vds 100V/div, Ch2: OUT 20V/div, Ch3: Vcin 200V/div, Ch4: Iin 1A/div

◆110Vac Full load (≒ 60W) Switching wave form



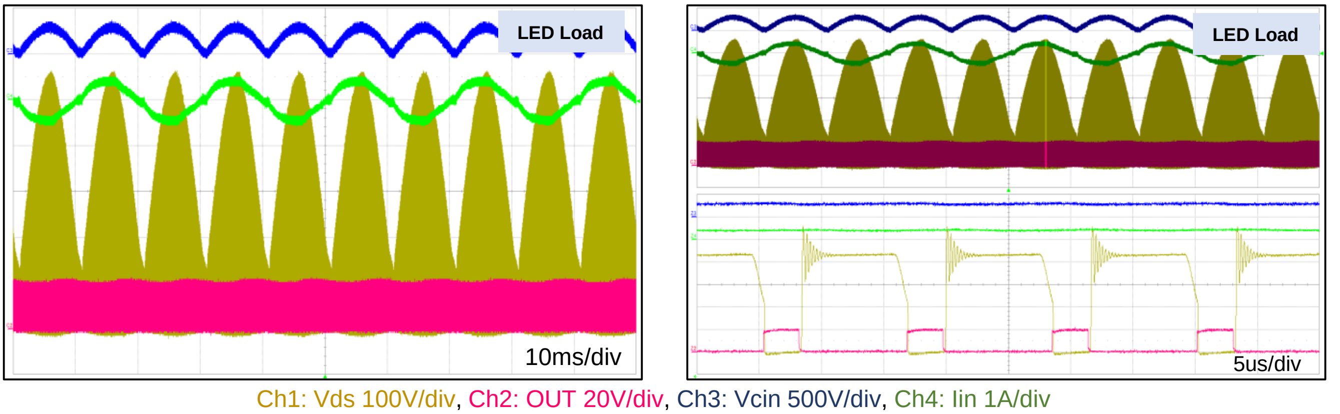
Ch1: Vds 100V/div, Ch2: OUT 20V/div, Ch3: Vcin 200V/div, Ch4: Iin 1A/div

◆220Vac Half load (≒ 30W) Switching wave form



Ch1: Vds 100V/div, Ch2: OUT 20V/div, Ch3: Vcin 500V/div, Ch4: Iin 0.5A/div

◆220Vac Full load (≒ 60W) Switching wave form



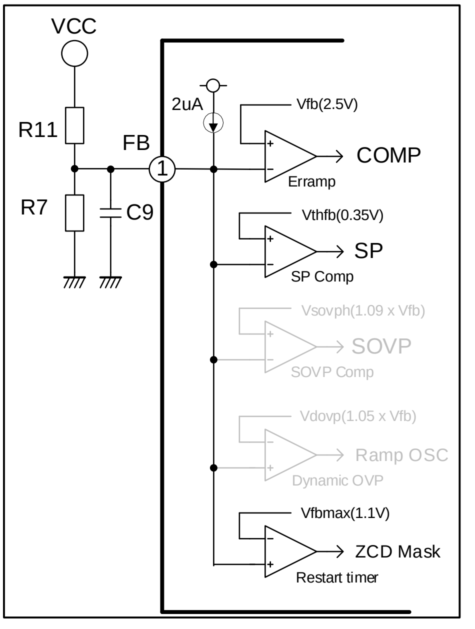
Ch1: Vds 100V/div, Ch2: OUT 20V/div, Ch3: Vcin 500V/div, Ch4: Iin 1A/div

10. Parts settings around the IC

10-1. FB pin

When applying FA1B00N to PFC flyback converter, use the COMP pin, which is the output of the internal error amplifier, as the feedback signal input. The FB pin is applied a voltage lower than the reference voltage Vfb of the error amplifier. On the other hand, the FB pin has a built-in short circuit protection, and it is necessary to set the FB pin voltage above the threshold voltage Vthfb (0.55V) when Vcc is the "OUT pin stop VCC pin threshold voltage" Voff. Also, during normal operation, it is recommended to use the FB pin above the "maximum oscillation frequency operating voltage" Vfbmax. When using for PFC flyback converter, the static overvoltage protection and dynamic overvoltage protection built into the FB pin cannot be used.

FB pin circuit



- Voff: 8V(MIN.)
- VCC: 19V
- Ipullup: -1.4μA(MAX.)
- Vthfb: 0.55V(MAX.)
- Vfbmax: 1.3V(MAX.)
- R11: 180kΩ
- Vfb: 2.475V(MIN.)

Calculate the resistance value of R7 above Vthfb.

$$0.55\mathrm{V} \div \left((8\mathrm{V} - 0.55\mathrm{V}) \div 180\mathrm{k\Omega} + 1.4\mu\mathrm{A} \right) = 12.9\mathrm{k\Omega} \qquad \underline{R7 > 12.9\mathrm{k\Omega}}$$

Calculate the resistance value of R7 that exceeds Vfbmax.

$$1.3\mathrm{V} \div \left((19\mathrm{V} - 1.3\mathrm{V}) \div 180\mathrm{k\Omega} + 1.4\mu\mathrm{A} \right) = 13.1\mathrm{k\Omega} \qquad \underline{R7 > 13.1\mathrm{k\Omega}}$$

Calculate the resistance value of R7 that is less than Vfb.

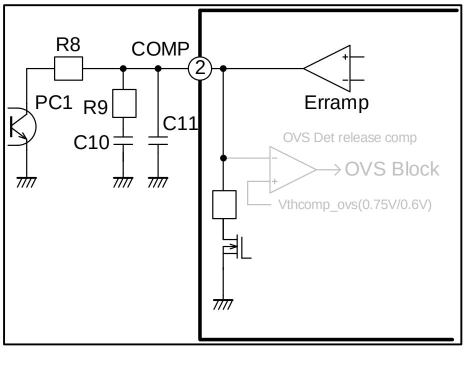
$$2.475\mathrm{V} \div \left((19\mathrm{V} - 2.475\mathrm{V}) \div 180\mathrm{k\Omega} + 2.6\mu\mathrm{A} \right) = 27.0\mathrm{k\Omega} \qquad \underline{R7 < 27.0\mathrm{k\Omega}}$$

From the above calculation results, the resistance value of R7 is set to 15 kΩ. C9 is connected with a 0.01μF ceramic capacitor to prevent malfunction due to noise.

10-2. COMP pin

As for the COMP pin, connect the collector pin of the photocoupler for feedback from the secondary side. Connect a capacitor so that the COMP pin voltage will be DC voltage. A CR filter may be added for stable operation. Please check the actual operation. The source current of the COMP pin is as low as -30uA, and R8 may be connected and adjusted for the purpose of suppressing over response to the secondary output. When connecting R8, select the resistor value so that the COMP pin voltage could be lowered below the “OUT pin stop COMP pin threshold voltage” Vthcomp.

COMP pin circuit



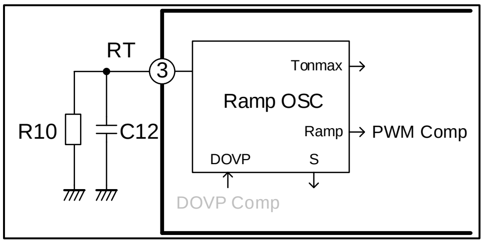
- R9: 4.7kΩ
- R8: 15kΩ
- C10: 0.47μF
- C11: 0.22μF

Please decide the above value after confirming the actual operation.

10-3. RT pin

Set the resistor value of the RT pin to be larger than the on-width required for the circuit. Each parameter used in the calculation is as follows.

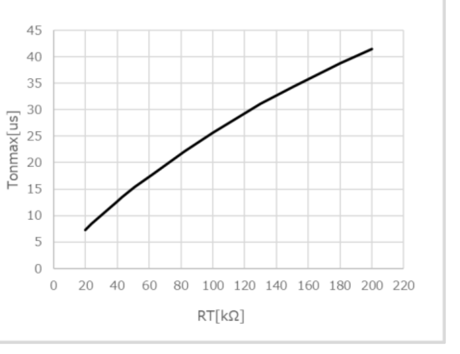
RT pin circuit



- Lp: 260μH
- Pout: 60W(target)
- Vac(min): 90Vrms
- η: 0.85
- NP1: 24Turn
- NS1: 5Turn

※η is the input / output conversion efficiency of PFC, and the power factor is assumed as 1.

Maximum on-range(Tonmax) vs. RT resistance(Rrt)



Calculate the peak current ILp flowing through the primary winding of the transformer.

$$\mathrm{D} = \frac{24\mathrm{V} \times 24 \div 5}{90 \times \sqrt{2} + 24\mathrm{V} \times 24 \div 5} = 0.475$$

$$\mathrm{I_{Lp}} = \frac{2 \times \sqrt{2} \times (60\mathrm{W} \div 0.85 \div 90\mathrm{V})}{0.475} = 4.67\mathrm{A}$$

Calculate on-time ton from the above ILp.

$$\mathrm{t_{on}} = \frac{260\mu\mathrm{H} \times 4.67\mathrm{A}}{90\mathrm{V} \times \sqrt{2}} = 9.54\mu\mathrm{s}$$

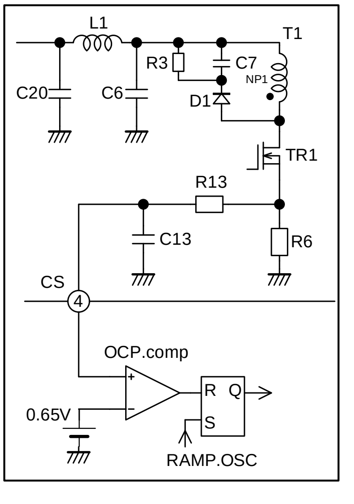
$$\mathrm{f_{swmin}} = \frac{0.475}{9.54\mu\mathrm{s}} = 49.8\mathrm{kHz}$$

From the calculation results and the graph of Tonmax and Rrt resistance in the data sheet, R10 is set to 36 kΩ. C12 is connected with a 0.01uF ceramic capacitor to prevent malfunction due to noise. Tonmax is the OUT pin width when the COMP pin voltage Vcomp is 4.2V. If Tonmax is set too large (R10 is made large), the fluctuation of the output width becomes large, and the power factor and THD may deteriorate. Select the resistance value after fully checking the actual operation.

10-4. CS pin

The surge current due to drive current of MOSFET_TR1 or the discharge current of the parasitic capacitance of the circuit flow through the current sensing resistor Rs. At the CS pin, connect a CR filter to prevent the OUT pin pulse from stopping due to false detection of these currents. After setting the cutoff frequency of the CR filter to be 1 to 2 MHz, check the actual operation and adjust.

CS pin circuit



- R13: 47Ω
- C13: 2200pF

Calculate the cutoff frequency.

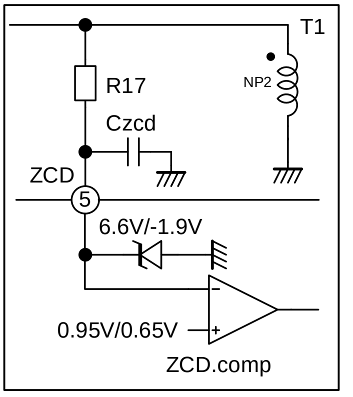
$$1 \div (2 \times \pi \times 100\Omega \times 2200\mathrm{pF}) = 1.54\mathrm{MHz}$$

In this reference design, R13 is set to 100Ω to enhance the filter function. Select the value after confirming the actual operation.

10-5. ZCD pin

The ZCD pin uses the auxiliary winding voltage to detect the timing when the transformer energy is reset and the secondary winding current becomes zero. The recommended current value of the internal Zener diode at the ZCD pin is ± 1.5mA. The current flowing through the Zener diode is limited by the resistor R17. The parameters used in the calculation are:

ZCD pin circuit



- NP1: 24 turn
- NP2: 4 turn
- NS1: 5 turn
- Vac(max): 264V
- Vout: 24V
- Vih: 5.6V(MAX.)
- Vil: -0.6V(MAX.)

Calculate the ZCD terminal voltage plus side.

$$(24\text{V} \times 4/5 - 5.6\text{V}) \div 1.5\text{mA} < \text{R17} \qquad \underline{\text{R17} > 9.1\text{k}\Omega}$$

Calculate the ZCD terminal voltage minus side.

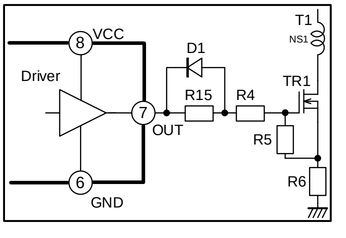
$$\left(-0.6\text{V} + \sqrt{2} \times 264\text{V} \times 4/24\right) \div 1.5\text{mA} < \text{R17} \qquad \underline{\text{R17} > 41.1\text{k}\Omega}$$

From the calculation results, R17 should be set to 41.1 kΩ or higher. In this reference design, 82kΩ is selected in consideration of the resistance value adjustment of R17. When determining the resistance value, make adjustments while checking the MOSFET turn-on timing and ZCD pin waveform in actual operation. The ZCD pin - GND pin capacitor Czcd is not mounted.

10-6. OUT pin

The OUT pin can directly drive the power MOSFET, but it must be used within the ratings of the source and sink current of the OUT pin. Make adjustments according to the circuit actually used and the power MOSFET. As a guide, set the lower limit of the resistance value. The parameters used in the calculation are:

OUT pin circuit



- Vol:1.2V(typ.), Isink=200mA
- Voh: 10V(MAX.), Isource=50mA
- Vcc: 12V (measurement conditions)
- VCC: 19V (VCC pin voltage during use)
- Io: 1000mA(sink)
- Io: 500mA(source)

Calculate the gate resistance Rg required when the power MOSFET is turned off, taking into account the internal resistance Rsink of the OUT pin.

$$19\text{V} \div (1.2\text{V} \div 200\text{mA} + \text{Rg}) < 1000\text{mA} \qquad \underline{\text{Rg} > 18.8\Omega}$$

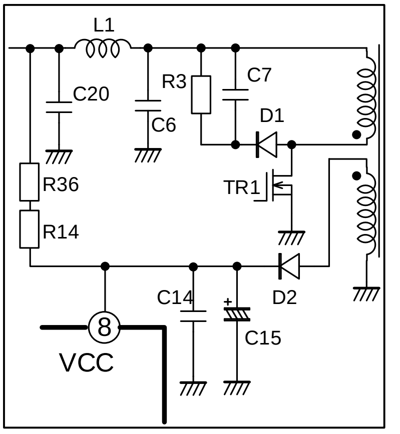
Calculate the OUT pin current at turn on, taking into account the internal resistance Rsource of the OUT pin when the current is source.

$$19\text{V} \div \left((12\text{V} - 10\text{V}) \div 50\text{mA}\right) = 475\text{mA}$$

From the calculation results, we set 22Ω for sink (off) and 22Ω + 100Ω for source (on). When the VCC voltage is 19V, the output current Io does not exceed 500mA due to the voltage drop inside the IC, but when connecting to a MOSFET, be sure to connect a resistor. Adjust the on / off timing in actual operation to determine the resistance value. If the VCC voltage fluctuates greatly, set the gate resistance at the maximum VCC voltage.

10-7. VCC pin

VCC端子回路



Auxiliary winding voltage is smoothed and supplied to the VCC pin. Since there is no auxiliary winding voltage when the IC is started, start it by connecting a start up resistor. The parameters used to calculate the start up resistor are:

- Vac(min): 90V
- Vac(max): 264V
- VCC: 19V
- Von(MAX.): 14V
- Istart(MAX.): 300uA

The startup current Istart is consumed when the IC starts. Therefore, the start resistor R36 + R14 must be able to flow at least Istart.

$$\left(90\text{V} \times \sqrt{2} - 14\text{V}\right) \div 300\mu\text{A} > \text{R36} + \text{R14} \qquad \underline{\text{R36} + \text{R14} < 378\text{k}\Omega}$$

During operation, a voltage is always applied to the start up resistor. It is necessary to consider the power loss due to the start up resistance. The start up resistor is calculated when this loss is assumed below 0.6W.

$$\left(264\text{V} \times \sqrt{2} - 19\text{V}\right)^2 \div 0.6\text{W} < \text{R36} + \text{R14} \qquad \underline{\text{R36} + \text{R14} > 209\text{k}\Omega}$$

In this reference design, the starting resistance is set to 220kΩ in order to shorten the starting time. The time it takes for the IC to start operating can be roughly calculated from the starting resistance and the capacitor.

$$47\mu\text{F} \times 220\text{k}\Omega \times \ln\left(\frac{90 \times \sqrt{2}}{90 \times \sqrt{2} - 13}\right) = 1.1\text{sec}$$

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